

Comparison of Growth Between *Morone* Hybrids (Palmetto and Sunshine) in Earthen Ponds

MATTHEW MCENTIRE¹, SCOTT SNYDER,[†] AND DON FREEMAN

Harry K. Dupree Stuttgart National Aquaculture Research Center, USDA/ARS, PO Box 1050,
Stuttgart, Arkansas 72160, USA

Abstract

Palmetto bass are produced by crossing the female striped bass, *Morone saxatilis*, with the male white bass, *Morone chrysops*; whereas, the sunshine bass is the reciprocal cross. The hybrid striped bass industry typically rears sunshine bass in earthen ponds, because of the ease of handling, availability, and early maturation of the white bass female broodstock. Growth performance has been assumed similar between the crosses. Under commercial pond conditions, sunshine bass (19.8 ± 0.4 g (mean \pm SEM)) and palmetto bass (23.2 ± 0.3 g) were grown to market size (617.0 ± 17.2 g sunshine and 620 ± 3.6 g palmetto) within 15 mo, yielding 4532.6 kg/ha. The net production between the crosses was not significantly different and averaged 4373.4 kg/ha. Feed conversion ratio (FCR) of sunshine bass (FCR 1.70) was better ($P = 0.0158$) than palmetto bass (FCR 1.76). Commercial processing metrics of each cross demonstrated significant differences, with sunshine bass exhibiting lower frame waste ($P = 0.0457$) than palmetto bass, probably due to fish body shape or conformational differences at this size. Without growth performance differences between the hybrids, there might be an advantage to rearing sunshine bass due to the slightly better FCR and increased skinless boneless fillet yield.

Morone hybrids, hybrid striped bass (HSB), combine the best traits of each parent due to heterosis, resulting in progeny that are superior in growth, survival, handling, and disease resistance as opposed to either parent during the time it takes to reach market size (Bishop 1968; Logan 1968; Williams 1971; Ware 1975; Bonn et al. 1976; Williams et al. 1981; Smith and Jenkins 1984; Tuncer et al. 1990). Palmetto bass, also referred to at the original cross, are produced by crossing female striped bass, *Morone saxatilis*, with male white bass, *Morone chrysops* (Bishop 1968; Kerby 1993). On the other hand, sunshine bass, or the reciprocal cross (female white bass by male striped bass), were the most prevalent cross used by 19 of 23 commercial producers in 1996 (Kahl 1997) and continue to be the predominant cross raised by the industry (Jim Ekstrom, president of Striped Bass Growers Association, pers. comm.). The preference

for sunshine bass is due to the availability, relative ease of handling, and early maturation of the female white bass (Scott and Crossman 1973; Bonn et al. 1976; Kohler 1994).

There is no clear evidence that one hybrid outperforms the other under commercial conditions (Harrell 1997). However, in recirculating tank systems, sunshine bass outperformed palmetto bass (Rudacille and Kohler 2000). A direct comparisons of the two cultured HSB crosses (palmetto versus sunshine) has not been conducted with adequate replication in the same environments, or over the range of conditions to which these fish are exposed in commercial production (Garber and Sullivan 2006). To address this concern, a direct comparison was made between the hybrids under commercial growing conditions in earthen ponds.

Materials and Methods

In September of 2001, three replicate ponds of each hybrid were stocked at a rate of 7398 fish/ha based on mean fish weights. Mean weights of sunshine and palmetto bass were 19.8 ± 0.4 g (mean \pm SEM) and 23.2 ± 0.3 g, respectively, as

¹ Correspondence to: Matthew.McEntire@ARS.USDA.GOV

[†]Present address: Scott Snyder, Clear Springs Foods, Inc., PO Box 712, Buhl, Idaho 83316, USA.

determined in 12 group weights of 25 fish per group for each cross. Sunshine bass were obtained from Keo Fish Farm, Keo, Arkansas, USA, from wild-caught white bass females and wild male striped bass, which were spawned the same week as the palmetto bass. Palmetto bass were produced from wild-caught female striped bass and wild male white bass provided by the Arkansas Game and Fish Commission Andrew H. Hulsey State Hatchery, Hot Springs, Arkansas, USA. Six rectangular (64.5×17.5 m averaging 1.1 m deep) 0.10 ha ponds were filled with well water and 45 kg of CaCl_2 was applied to each pond as a osmoregulatory or stress relieving treatment for post-stocking handling. Electric paddlewheel aeration (5 hp/ha) started at 2000h and was turned off in the morning when the dissolved oxygen was above 5 mg/L at water temperatures greater than 24 C. Additional well water was added as needed to compensate for evaporative losses, but no flushing of the ponds occurred. Over the 440 d trial, water quality parameters were monitored as follows: dissolved oxygen and temperature were measured daily (Oxi 330i, WTW Inc., College Station, TX, USA), while pH (Model 290A, Orion Research Inc., Boston, MA, USA), total ammonia nitrogen (TAN), and nitrite (Nessler and diazotization method respectfully, DR/4000, Hach, Ames, IA, USA) were measured weekly or more often as conditions warranted to ensure parameters remained within optimal conditions for *Morone* culture (Boyd and Tucker 1998). The resulting three palmetto and three sunshine ponds were fed a 45% protein, 18% fat extruded diet (Nelson's Silver Cup, Tooele, UT, USA) similar to other reported hybrid studies (Rawles et al. 2009 and Rawles et al. 2010). Diets were fed twice daily to apparent satiation, except when water temperatures averaged 11 C or below, when feed was offered once during the warmest part of the day. In addition, the staff responsible for feeding the ponds was blinded to the random assignment of pond treatments.

Fish were sampled once in the spring and fall of 2002 when water temperatures permitted handling the fish. At least 50 fish from each pond were sampled by seining to determine mean fish weight, estimated percent weight gain, and

estimated feed conversion ratio ($\text{FCR} = \text{g dry feed/g weight gain}$). In addition, 10 fish per pond were bled and returned to the pond in the spring and fall to examine the stress response between crosses reported in Davis et al. 2004. During the fall sampling, 30 sunshine and 30 palmetto bass were removed from the study to examine resting insulin-like growth factor-I (IGF-I) and insulin-like growth factor-I binding protein (IGF-I BP) levels as reported in Davis and Peterson (2005).

At the conclusion of the study (December 2002; 440 d post-stocking), fish in each pond were harvested by seining, counted, and group weighed (10 fish per group weight). From each pond, 100 fish were sampled to determine fish weight and size distributions by pond. Mean fish weight, net growth, net feed, $\text{FCR} = \text{g dry feed fed per pond/g fish weight gain per pond}$, total number of fish, fish weight gain, total yield, net production, and average daily gain were calculated per pond. After harvest, four pooled samples of about 100 fish, two of each cross ($n = 200$ fish/cross), were taken to a commercial processing facility (Parieland Seafoods, Pinckneyville, IL, USA) to determine carcass yield characteristics. The fish were filleted and divided into boneless skinless fillets, ribs (meat and bone removed from fillet), guts, and frames (head, spine, and tail). Responses for each hybrid were compared by analysis of variance using PROC Mixed in SAS version 9.2 (SAS Institute, Inc., Cary, NC, USA). Differences among responses were declared significant at $P \leq 0.05$.

Results

Two weeks post-stocking the pond water quality parameters (mean \pm SEM) were 17.5 ± 0.0 C, 5.9 ± 0.1 mg/L dissolved oxygen, 8.0 ± 0.1 pH, 154 ± 0 mg/L CaCO_3 alkalinity, 68 ± 0 mg/L CaCO_3 hardness, 90 ± 0 mg/L chloride, 0.5 ± 0.1 mg/L TAN, 0.02 ± 0.01 mg/L unionized ammonia, and 0.0 ± 0.0 mg/L nitrite. Water temperature averaged 19.8 ± 0.2 C throughout the 440-d trial and ranged from 0.8 to 34.2 C. Seasonal pond temperature averages were 15.6 ± 0.4 C for fall (mid-September to December 1), 8.8 ± 0.2 C winter, 17.6 ± 0.3 C

TABLE 1. Comparison of sunshine and palmetto bass production characteristics (mean \pm standard error of mean, n = sample size), based upon the initial and three sampling times, contrasted to the initial sampling time. Significant ($P \leq 0.05$) differences between taxa are indicated by an asterisk (*).

	Sunshine bass	<i>n</i>	Palmetto bass	<i>n</i>	<i>P</i> -value
Initial stocking – September 2001					
Initial fish weight (g)	19.8 \pm 0.4*	12	23.2 \pm 0.3	12	<0.0001
Fish weight per pond (kg)	14.85 \pm 0.02*	3	17.36 \pm 0.01	3	<0.0001
Number fish per pond	748.7 \pm 0.7	3	749.3 \pm 0.7	3	0.5185
Spring sampling – April 2002					
Fish weight (g)	83.8 \pm 1.4	3	85.4 \pm 3.0	3	0.6557
Estimated net growth (kg)	47.9 \pm 1.0	3	46.7 \pm 2.3	3	0.6423
Net feed (kg)	67.8 \pm 0.3	3	71.0 \pm 1.8	3	0.1538
Estimated FCR	1.42 \pm 0.02	3	1.52 \pm 0.04	3	0.0952
Fall sampling – October 2002					
Fish weight (g)	507.4 \pm 11.1	3	503.5 \pm 6.0	3	0.7739
Estimated net growth (kg)	332.0 \pm 9.2	3	330.6 \pm 6.9	3	0.9130
Net feed (kg)	539.8 \pm 6.7*	3	604.8 \pm 19.6	3	0.0351
Estimated FCR	1.63 \pm 0.05	3	1.83 \pm 0.09	3	0.1041
Final harvest – December 2002					
Fish size distribution					
Fish weight (g)	634.1 \pm 6.4	300	621.3 \pm 5.7	300	0.1359
Biggest fish (g)	955.0 \pm 46.4	3	893.0 \pm 63.4	3	0.4741
Smallest fish (g)	288.7 \pm 15.1	3	322.0 \pm 45.0	3	0.5215
Pond yields					
Fish weight (g)	617.0 \pm 17.2	3	620.4 \pm 3.6	3	0.8549
Net growth (kg)	438.3 \pm 12.8	3	478.9 \pm 15.3	3	0.1114
Net feed (kg)	721.1 \pm 17.2*	3	811.6 \pm 27.1	3	0.0480
Feed conversion ratio	1.70 \pm 0.01*	3	1.76 \pm 0.00	3	0.0158
Total number fish	710.3 \pm 4.8*	3	771.7 \pm 20.2	3	0.0420
Fish weight gain (g/fish)	597.1 \pm 17.2	3	597.2 \pm 3.6	3	0.9953
Total yield (kg/ha)	4331.9 \pm 126.7	3	4733.3 \pm 151.0	3	0.1114
Net production (kg/ha)	4317.0 \pm 126.7	3	4715.9 \pm 151.0	3	0.1130
Average daily gain (%/d)	6.5 \pm 0.2	3	6.0 \pm 0.2	3	0.1953

FCR = feed conversion ratio.

spring (March 1 to June 1), 28.2 ± 0.1 C summer, and 18.7 ± 0.3 C fall. Unionized nitrogen, TAN, pH, and nitrite averaged 0.10 ± 0.01 mg/L, 0.75 ± 0.03 mg/L, 8.25 ± 0.03 , and 0.00 ± 0.00 mg/L, respectively, during the feeding trial. The highest TAN reading (2.95 mg/L) occurred in October 2002 in one pond after a phytoplankton bloom die-off and fish refused to feed; the corresponding unionized nitrogen was 0.4 mg/L. However, the following week fish in the same pond resumed feeding and exhibited the highest consumption among the ponds for that week. With the exception of the previously mentioned event, all water quality parameters were within guidelines set for good growth of hybrid striped bass (Nicholson et al. 1990).

The hybrids consumed 90% of the feed from mid-April to the end of October, when water

temperature averaged 24.7 C. Fish actively consumed feed 305 d out of the 440-d trial. Generally fish would eat daily if the water temperature was 15 C and above. When water temperature ranged from 10 to 15 C the fish would typically feed well one to two times a week, but below 10 C fish feeding activity on the floating feed was greatly reduced.

At stocking, the mean fish weights of each cross were slightly different ($P < 0.001$) from one another, with the palmetto bass being 3.4 g/fish heavier on average due to tight standard errors among sample group weights (Table 1). This resulted in different total weights (14.85 ± 0.02 kg = 748.7 individual sunshine bass; 17.36 ± 0.01 kg = 749.3 individual palmetto bass) stocked into each pond to achieve the target of 750 fish per pond.

The first fish sampling occurred when water temperatures averaged $22.6 \pm 0.1^\circ\text{C}$ in late April of 2002 at which time mean fish weights were 83.8 ± 1.4 g for sunshine and 85.4 ± 3.0 g for palmetto bass. The estimated net growth ($46.7\text{--}47.9$ kg) and FCR ($1.42\text{--}1.52$) were not different between sunshine bass and palmetto bass. In early October of 2002, water temperatures averaged $21.8 \pm 0.3^\circ\text{C}$ and the sunshine bass mean weight (507.4 ± 11.1 g) was not significantly different ($P = 0.7739$) from the palmetto bass mean weight (503.5 ± 6.0 g). The amount of feed consumed by October of 2002 was different between the crosses, with palmetto bass consuming 65 kg more feed than sunshine bass. However, the estimated net growth and FCRs were not significantly different between the crosses at this sampling point. At harvest in December of 2002, there was no difference ($P = 0.1359$) between the sunshine bass, which averaged 634.1 ± 6.4 g (range 268–1028 g) and the palmetto bass, which averaged 621.3 ± 5.7 g (range 245–1015 g).

Counting all of the fish in the pond revealed a statistical difference between treatments, with 710.3 ± 4.8 for the sunshine bass ponds and 771.7 ± 20.2 for the palmetto bass ponds. Taking into account the actual number of fish in each pond, the amount of weight gain on a per fish basis were remarkably similar with 597.1 ± 17.2 g for sunshine and 597.2 ± 3.6 g for palmetto bass. The final fish weight-frequency distributions of both hybrids overlapped and appeared no different from a normal bell curve. Net feed fed was statistically different ($P = 0.0480$) between the crosses as it was in the fall sampling with the palmetto bass consuming more feed. The estimated FCR from the fall sampling trended toward the final FCR of 1.70 ± 0.01 for sunshine bass, which was significantly lower ($P = 0.0480$) than the 1.76 ± 0.00 for the palmetto. Total fish numbers and weights by treatment were 2131 sunshine bass, weighing 1314.8 kg, and 2315 palmetto bass, weighing 1436.6 kg. The average daily weight gain (% weight gain/440 d) was not statistically different ($P = 0.1953$) between the crosses. Net production was 4317 ± 126.7 kg/ha and 4715.9 ± 151.0 kg/ha for sunshine and

TABLE 2. At a commercial processing facility 195 sunshine bass or 193 palmetto bass were filleted and the resulting components weighed in grams (means \pm standard error of mean). Below in parentheses the component weights are represented as a percentage of total fish weight. The statistical differences ($P \leq 0.05$) between sunshine bass and palmetto bass are indicated with an asterisk (*).

Fish component	Sunshine bass	Palmetto bass	P-value
Frame	$280.6 \pm 3.6^*$ (45.46 \pm 0.06)%	302.7 ± 3.3 (48.44 \pm 0.24)	0.0457 0.0410
Skinless fillet	255.3 ± 3.3 (41.34 \pm 0.04)	253.7 ± 2.2 (40.80 \pm 0.21)	0.8327 0.1638
Boneless skinless fillet	185.1 ± 2.4 (29.97 \pm 0.03)%	161.6 ± 1.8 (25.93 \pm 0.18)	0.0501 0.0386
Rib	70.2 ± 0.9 (11.37 \pm 0.02)	92.1 ± 1.1 (14.87 \pm 0.17)	0.0783 0.0531
Gut	81.4 ± 1.1 (13.19 \pm 0.02)	66.3 ± 0.8 (10.76 \pm 0.15)	0.0680 0.0624
Total fish weight	617.4 ± 8.0	622.7 ± 4.8	0.6709

palmetto bass, respectively. Fillet and carcass processing yields were significantly different between the two crosses. Sunshine bass exhibited a slightly higher ($P = 0.0386$) boneless skinless fillet yield of $29.9 \pm 0.5\%$ as opposed to palmetto $26.0 \pm 0.5\%$ (Table 2). In addition, the sunshine bass ($45.46 \pm 0.06\%$) had a lower ($P = 0.0410$) frame waste than the palmetto bass ($48.44 \pm 0.24\%$).

Discussion

This study corroborates the results from a previous study by Harrell (1997) in that there were no differences in mean fish growth or final size between these two moronid hybrids. Due to an unintended difference in the stocking rate as a result of stocking by average number/weight rather than fish count, one palmetto bass pond totaled 811 fish instead of 750, and the extra 61 fish in this pond resulted in an insignificant but higher palmetto pond yield that added variability to the yield statistics. However, on a net grams gained per fish basis, sunshine bass (597.1 ± 17.2 g) were no different than palmetto bass (597.2 ± 3.6 g), hence there was not a performance difference in attaining market size. These results are different from those of Rudacille and Kohler (2000), which suggested that sunshine bass perform better than palmetto

bass based upon data extrapolated from 50 sunshine bass from Arkansas and 50 palmetto bass from Texas randomly divided into four different aquaria and grown for 84 d. In contrast, our results comparing more than 2000 individuals from each cross from the same geographical area under the same conditions in six replicated 0.1 ha ponds strongly supports the notion that there are no differences in mean fish growth or final size between these two hybrids when grown under the same culture conditions to market size (600 g).

Generally, fish fed in tanks exhibit FCRs that are significantly better than pond FCRs and smaller fish exhibit better FCRs than larger fish, given the same diet and water quality. This was found true in sunshine bass grown from about 80 g through market size; recirculating tank (8 m³) FCRs were 1.58–1.72 (Rawles et al. 2006) and were better than FCRs (1.98–2.19) in ponds (Rawles et al. 2009) when the same diets were fed in both trials. However, the fish size comparison did not hold true in recirculating tanks with sunshine, palmetto, and white bass having FCRs of 2.02, 2.63, and 1.98 for (40–120 g) fish size and FCR 1.28, 1.26, and 1.88 for (150–500 g) fish size, respectively (Rudacille and Kohler 2000). In the referenced study there was a reliance on feeding a percent body weight instead of satiation feeding as was used in this pond study. Palmetto bass reared in ponds had FCRs of 1.6–2.34 (Kerby et al. 1983, Kerby et al. 1987, Zhang et al. 1994). In this study FCRs among sunshine bass (1.70) reared in ponds were slightly better than those of the palmetto bass (1.76). These observations might support the notion that palmetto bass are more like the maternal parent's feeding habits at warm temperatures, which could be characterized as slower for a longer duration than sunshine bass without reaching apparent satiation. In that case, the floating feed might blow to the side of the pond and be less available to palmetto bass given the same feed management practices. This could result in the statistical difference in FCRs between the hybrids over the 440 d growing season. All the ponds in this study were fed over the course of 2–3 h/d until there was a significant decrease in feeding activity and there were no

observations of uneaten food that differed among ponds.

Processing yield percentages in our fish were lower than those of palmetto bass ($33.2 \pm 0.1\%$) or sunshine bass ($33.6 \pm 0.6\%$; $34.9 \pm 0.4\%$) reported in the literature (Swann et al. 1994; Rudacille and Kohler 2000). The commercial facility familiar with hybrid striped bass processing was likely different from the previous reports because of the volume of fish and the rate at which the fish were processed. The previous reports represented a smaller sample size with a single person performing the processing; while this study's commercial processor utilized professional staff trained for a combination of skill and speed. From the commercial processing data the sunshine skinless boneless fillet yield of 30% were larger than the palmetto yield of 26%. This difference corresponded to an increase in the amount of waste in the ribs and frame in the palmetto bass. For example, if the rib weights are added back to the fillet weights, the resulting bone-in fillet weights are not different between the two hybrids ($P = 0.8327$).

Frame differences between the hybrids suggest that palmetto bass are larger in frame at $48.4 \pm 0.5\%$ than sunshine bass at $45.5 \pm 0.5\%$. This difference could be due to a body conformational shift from the short and squat sunshine bass to a longer more perciform shape in the palmetto bass. Fish length or body conformation was not examined in this study. Future studies should examine the impact of maternal versus paternal heritability of body shape or conformation in palmetto and sunshine bass. This might best be accomplished by examining the heritability of body shape or conformation within the hybrids from known families of striped bass and white bass with different body shape conformations. In European sea bass (*Dicentrarchus labrax*) body shape has a high genetic component (Costa et al. 2010) and should be indicative of results in *Morone* hybrids because of their genetic relatedness. Such research could yield great versatility and economic benefit to producers by allowing them to selectively breed to increase fillet yield or optimize broodstock conformation according to the best economic return. We demonstrated about a 4% difference

in boneless skinless fillet yield between the hybrids, if through selective breeding you could raise the fillet yield another 10–15% a fillet market might be a real possibility. Currently most hybrids are sold whole on ice. However, increasing the fillet yield might allow expansion of the hybrid striped bass fillet market. Future research is needed to determine if this is feasible.

Acknowledgments

The gift of sunshine bass by Keo Fish Farm, Keo, AR, USA, and palmetto bass by Andrew H. Hulsey AGFC State Hatchery, Hot Springs, AR, USA, is gratefully acknowledged. The authors thank Steven Rawles for valuable comments on the manuscript. This study was funded by the USDA/ARS under project number 6225-31630-006-00D. Animal care and experimental protocols were approved by the Harry K. Dupree Stuttgart National Aquaculture Research Center Institutional Animal Care and Use Committee and conformed to Agricultural Research Service Policies and Procedures 130.4 and 635.1. USDA is an equal opportunity provider and employer. Mention of trade names or commercial products in this article is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

Literature Cited

- Bishop, R. D.** 1968. Evaluation of the striped bass (*Roc-cus saxatilis*) and white bass (*R. chrysops*) hybrids after two years. Proceedings of the Annual Conference of the Southeast Association of Game and Fish Commissioners 21:245–253.
- Bonn, E. W., W. M. Bailey, J. D. Bayless, K. E. Erikson, and R. E. Stevens.** 1976. Guidelines for striped bass culture. Southern Division, American Fisheries Society, Bethesda, Maryland, USA.
- Boyd, C. E. and C. S. Tucker.** 1998. Pond aquaculture water quality management. Kluwer Academic Publishers, Boston, Massachusetts, USA.
- Costa, C., M. Vanderputte, F. Antonucci, C. Boglione, P. Menesatti, S. Cenadelli, K. Parati, H. Chavanne, and B. Chatain.** 2010. Genetic and environmental influences on shape variation in the European sea bass (*Dicentrarchus labrax*). Biological Journal of the Linnean Society 101:427–436.
- Davis, K. B. and B. C. Peterson.** 2005. Comparison of insulin-like growth-factor-I and insulin-like factor binding protein concentrations of the palmetto and sunshine bass and the effects of gender and stress. Journal of the World Aquaculture Society 36:384–400.
- Davis, K. B., D. W. Freeman, and G. S. Snyder.** 2004. Comparison of the stress response to seining between hybrid sunshine *Morone chrysops* × *M. saxatilis* and palmetto *M. saxatilis* × *M. chrysops* bass. Journal of the World Aquaculture Society 35:109–112.
- Garber, A. and C. Sullivan.** 2006. Selective breeding for the hybrid striped bass (*Morone chrysops*, Rafinesque *M. saxatilis*, Walbaum) industry: status and perspectives. Aquaculture Research 37:319–338.
- Harrell, R.** 1997. Hybridization and genetics. Pages 217–234 in R. Harrell, editor. Striped bass and other *Morone* culture. Elsevier Science, Amsterdam, The Netherlands.
- Kahl, K. H.** 1997. Marketing in the hybrid striped bass industry. Aquaculture Magazine 23:27–33, 34, 36, 38, 40–42.
- Kerby, J. H.** 1993. The striped bass and its hybrids. Pages 251–306 in R. R. Stickney, editor. Culture of non-salmonid freshwater fishes, 2nd edition. CRC Press, Boca Raton, Florida, USA.
- Kerby, J. H., L. C. Woods III, and M. T. Huish.** 1983. Pond culture of striped bass × white bass hybrids. Journal of the World Mariculture Society 14:613–623.
- Kerby, J. H., J. M. Hinshaw, and M. T. Huish.** 1987. Increased growth and production of striped bass × white bass hybrids in earthen ponds. Journal of the World Aquaculture Society 18:35–43.
- Kohler, C.** 1994. Habituation to captivity and controlled spawning of white bass. Transactions of the American Fisheries Society 123:964–974.
- Logan, H. J.** 1968. Comparison of growth and survival rates of striped bass and striped bass × white bass hybrids under controlled environments. Proceedings of the Annual Conference of the Southeast Association of Game and Fish Commissioners 21:260–263.
- Nicholson, L. C., L. C. Woods III, and J. G. Woiwode.** 1990. Intensive culture techniques for the striped bass and its hybrids. Pages 141–158 in R. M. Harrell, J. H. Kerby, and R. V. Minton, editors. Culture and propagation of striped bass and its hybrids. American Fisheries Society, Southern Division, Striped Bass Committee, Bethesda, Maryland, USA.
- Rawles, S. D., M. Riche, T. G. Gaylord, J. Webb, D. W. Freeman, and M. Davis.** 2006. Evaluation of poultry by-product meal in commercial diets for hybrid striped bass (*Morone chrysops* ♀ × *M. saxatilis* ♂) in recirculated tank production. Aquaculture 259:377–389.
- Rawles, S. D., T. G. Gaylord, M. E. McEntire, and D. W. Freeman.** 2009. Evaluation of poultry by-product meal in commercial diets for hybrid striped bass, *Morone chrysops* ♀ × *Morone saxatilis* ♂, in pond production. Journal of the World Aquaculture Society 40:141–156.
- Rawles, S. D., T. G. Gaylord, G. S. Snyder, and D. W. Freeman.** 2010. The influence of protein and energy density in commercial diets on growth, body composition, and nutrient retention of sunshine bass, *Morone*

- chrysops*♀ × *Morone saxatilis*♂, reared at extreme temperature. Journal of the World Aquaculture Society 41:165–178.
- Rudacille, J. B. and C. C. Kohler.** 2000. Aquaculture performance comparison of sunshine bass, palmetto bass, and white bass. North American Journal of Aquaculture 62:114–124.
- Scott, W. B. and E. J. Crossman.** 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada, Ottawa, Canada.
- Smith, T. I. J. and W. E. Jenkins.** 1984. Controlled spawning of F₁ hybrid striped bass (*Morone saxatilis* × *M. chrysops*) and rearing of F₂ progeny. Journal of the World Mariculture Society 15:147–161.
- Swann, D. L., J. R. Riepe, J. D. Stanley, M. E. Griffin, and P. B. Brown.** 1994. Cage culture of hybrid striped bass in Indiana and evaluation of diets containing three levels of dietary protein. Journal of the World Aquaculture Society 25:281–288.
- Tuncer, H., R. M. Harrel, and E. D. Houde.** 1990. Comparative energetics of striped bass (*Morone saxatilis*) and hybrid (*M. saxatilis* × *M. chrysops*) juveniles. Aquaculture 86:387–400.
- Ware, F. J.** 1975. Progress with *Morone* hybrids in freshwater. Proceedings of the Annual Conference of the Southeast Association of Game and Fish Commissioners 28:48–54.
- Williams, H. M.** 1971. Preliminary studies of certain aspects of life history of the hybrids (striped bass × white bass) in two South Carolina reservoirs. Proceedings of the Annual Conference of the Southeast Association of Game and Fish Commissioners 24:424–430.
- Williams, J. E., P. A. Sandifer, and J. M. Linberg.** 1981. Net-pen culture of striped bass × white bass hybrids in estuarine waters of South Carolina: a pilot study. Journal of the World Mariculture Society 12:98–110.
- Zhang, Q., R. C. Reigh, and W. R. Wolters.** 1994. Growth and body composition of pond-raised hybrid striped basses, *Morone saxatilis* × *M. chrysops* and *M. saxatilis* × *M. mississippiensis*, fed low and moderate levels of dietary lipid. Aquaculture 125:119–129.